Review of literature

Vermiculture is practiced for the mass production of earthworms with the multiple objectives of waste management, soil fertility and detoxification, and production of vermicompost for sustainable agriculture. The practice was started in the middle of 20th century and the first serious experiments were established in Holland in 1970, and subsequently in England, and Canada. Later vermiculture practices were followed in USA, Italy, Philippines, Thailand, China, Korea, Japan, Brazil, France, Australia and Israel (Edward, 1988).

Vermicomposting is the process of turning organic debris into worm casting (also known as worm humus or worm manure). It is a simple biotechnological process of composting in which certain species of earthworms are used to enhance the process of waste conversion and to produce a better end product. Vermicomposting differs from composting in several ways (Gandhi et al. 1997). It is a mesophilic process, utilizing microorganisms and earthworms that are active at 10-32°C (not ambient temperature but temperature within the pile of moist organic material). The process is faster than composting where waste material passes through the earthworm gut. Earthworms are capable of transforming garbage into 'gold' (Vermi Co 2001, Tara Crescent 2003).

Vermicompost is an excellent, nutrient-rich organic fertilizer and soil conditioner (Coyne et al., 2008). The process of vermicasting is undergoing research as a treatment for organic waste in sewage and wastewater plants around the world (Zularisam et al., 2010; Xing et al., 2011).

In the world of conventional composting, the rule-of-thumb is that one ton of inputs results in one cubic yard of compost, the weight of which varies with moisture content but is typically about ½ ton. In other words, 50% of the mass is lost, mostly as moisture and CO_2. Some N is lost as ammonia, but if the process is well managed the N loss is minimized (Rink et al, 1992). Of course, the final weight and volume of product varies with original feedstock, bulking agent used, etc., but the above rule-of-thumb is a handy way to quickly calculate output.

Vermicomposting is a bit more variable. This is because there is more variation in how the process is carried out. In composting, mixtures of high-N and high-C materials are made at the start and nothing is added to the mix thereafter. In vermicomposting, the high-C materials are used as bedding, while the high-N materials are generally feed stocks. Although similar processes are taking place in the bed (including conventional composting due to the action of micro-organisms), some systems encourage the addition over the course of the process of greater amounts of N relative to C than would be the case with conventional composting. This is because the feeds are added to the surface of the pile or windrow incrementally, rather than mixed in at the beginning. Since some high-N materials (e.g., fresh food wastes) can be higher in initial water content than high-C bedding materials, weight losses during the vermicomposting process can be higher (Munroe, 2004). Another factor reducing final output quantities in vermicomposting is the amount of material converted into worm biomass. This material is largely lost to the final product because most of the worms are removed from the product prior to completion of the process. Alternatively, vermicomposting processes can also allow for higher amounts of overall C to be processed. For instance, shredded paper and cardboard can be converted into vermicompost with the addition of as little as 5% poultry manure, by volume (GEORG, 2004). The result of this process is a product weight closer to 50% of the initial input weight.

In general, outputs from vermicomposting processes can vary from about 10% to closer to 50% of the original weight of the inputs. This will vary with the nature of the inputs and the system used. The greater the proportion of high-C inputs to high-N inputs, the greater will be the weight of final output as a proportion of input weight. If estimating the amount of output is important, it can be tested by running a bench or pilot-scale trial for several months (GEORG, 2004).

Compost is higher in ammonium, while vermicompost tended to be higher in nitrates, which is the more plant-available form of nitrogen (Atiyeh et al., 2000). Hammermeister et al. (2004) indicated that "Vermicomposted manure has higher N availability than conventionally composted manure on a weight basis". They also showed that the supply rate of several nutrients, including P, K, S and Mg, were increased by vermicomposting as compared with conventional composting. These results are typical of what other researchers have found (e.g., Short et al., 1999; Saradha, 1997, Sudha and Kapoor, 2000). It appears that the process of vermicomposting tends to result in higher levels of plant availability of most nutrients than does the conventional composting process.

In conventional composting, the ideal moisture-content range for materials is 45-60% (Rink et al, 1992). In contrast, the ideal moisture-content range for vermicomposting is 70-90%.

Within this broad range, researchers have found slightly different optimums: for some (Dominguez and Edwards, 1997) the 80-90% range is best with 85% optimum, while for others (Nova Scotia researchers), 75-80% moisture contents produced the best growth and reproductive response (GEORG, 2004). Both of these studies found that average worm weight increased with moisture content (among other variables), which suggests that vermiculture operations designed to produce live poultry feed or bait worms (where individual worm size matters) might want to keep moisture contents above 80%.

There may be differences in vermicomposting methods depending on the climate (Baley,2016). Compost worms can survive temperatures in the mid-30s but prefer a range in the 20s (^{o}C). Above 35^{o}C will cause the worms to leave the area. If they cannot leave, they will quickly die. In general, warmer temperatures (above 20^{o} C) stimulate reproduction. *E. fetida* is certainly not the only epigenic worm, but it is the one most often used for composting purposes in Northern climates. It can handle a wide temperature range (between 0 and 35^{o} C). Compost worms will redistribute themselves within piles, beds or windrows according to temperature gradients (Munroe, 2004).

The major drawback of the vermicomposting process is that the temperature is not high enough for an acceptable pathogen kill. Whereas in traditional thermophilic composting the temperatures exceed 70°C, the vermicomposting processes must be maintained at less than 35°C. A study has examined the possibility of integrating traditional thermophilic composting and vermicomposting (Ndegwa and Thompson, 2001). The work involved combining pertinent attributes from each of the two processes to enhance the overall process and improve the product qualities. The two approaches investigated in the study related to: (i) pre-composting followed by vermicomposting; and (ii) pre-vermicomposting followed by composting. The duration of each of the combined operations viz. composting and vermicomposting was four weeks. A comparison was made with vermicomposting alone (duration: 56 days). The results indicated that the combination of the two processes shortened the stabilization time and improved product quality. Furthermore, the resultant product was more stable and consistent, had less potential impact on the environment, and met pathogen reduction requirements.

There are a number of other parameters of importance to vermicomposting and vermiculture i.e., Ph, salt content etc. Worms can survive in a pH range of 5 to 9 (Edwards, 1998). Most experts feel that the worms prefer a pH of 7 or slightly higher. Nova Scotia researchers found that the range of 7.5 to 8.0 was optimum (GEORG, 2004). In general, the pH of worm beds tends to drop over time. If the food sources are alkaline, the effect is a moderating one, tending to neutral or slightly alkaline. If the food source or bedding is acidic (coffee grounds, peat moss) then the pH of the beds can drop well below 7. This can be a problem in terms of the development of pests such as mites. The pH can be adjusted upwards by adding calcium carbonate. In the rare case where they need to be adjusted downwards, acidic bedding such as peat moss can be introduced into the mix (Munroe, 2004).

Worms are very sensitive to salts, preferring salt contents less than 0.5% (Gunadi et al., 2002). If saltwater seaweed is used as a feed (and worms do like all forms of seaweed), then it should be rinsed first to wash off the salt left on the surface. If manures are to be used as bedding, they can be leached first to reduce the salt content. This is done by simply running water through the material for a period of time (Gaddie, 1975). If the manures are pre-composted outdoors, salts will not be a problem.

The red worm *Eisenia foetida* is widely considered as the best species at converting organic matter into compost; what is more, it feeds intensively and breeds most quickly. It favors rapid production of high quality compost, which can successfully be used as organic fertilizer (Rosik-Dulewska et al., 2014). Garg et al (2006) conducted a study (100 days duration) to evaluate the efficiency of *Eisenia foetida* for decomposition of different types of organic substrates (kitchen waste, agro-residues, institutional and industrial wastes including textile industry sludge and fibres) into valuable vermicompost. The data reveals that vermicomposting (using *E. foetida*) is a suitable technology for the decomposition of different types of organic wastes (domestic as well as industrial).

Vermicomposting of organic waste has an important part to play in an integrated waste management strategy. In a study, Shahmansouri et al (2005) investigated the possibility of heavy metals (Cr, Cd, Pb, Cu, and Zn) accumulation in sewage sludge vermicompost with two groups of Iranian and Australian earthworms. They used *Eisenia foetida* in the vermicomposting process. The results indicated that heavy metals concentration decreased with increasing vermicomposting time. Comparison of the two groups of earthworms showed that the Iranian earthworms consumed higher quantities of micronutrients such as Cu and Zn comparing with the Australian earthworms, while the bioaccumulation of non-essential elements such as Cr, Cd, and

Pb by the Australian group was higher. The significant decrease in heavy metal concentrations in the final vermicompost indicated the capability of both Iranian and *Australian E. fetida* species in accumulating heavy metals in their body tissues.

Vermicompost is an excellent soil additive made up of digested compost. Worm castings are much higher in nutrients and microbial life and therefore, are considered as a higher value product (Adhikary, 2012). Worm castings contain up to 5 times the plant available nutrients found in average potting soil mixes. Chemical analysis of the castings showed that it contains 5 times the available nitrogen, 7 times the available potash and 1.5 times more calcium than that found in 15 cm of good top soil (Ruz-Jerez,1992; Parkin, 1994). In addition, the nutrient life is up to 6 times more in comparison to the other types of potting mixes.

There have been several reports that earthworms and its vermicompost can induce excellent plant growth and enhance crop production. A study was made on the impact of vermicompost on ricelegume cropping system in India. Integrated application of vermicompost, chemical fertilizer and biofertilizers (Azospirillum & phosphobacteria) increased rice yield by 15.9% over chemical fertilizer used alone. The integrated application of 50% vermicompost, 50% chemical fertilizer and biofertilizers recorded a grain yield of 6.25 and 0.51 ton/ha in the rice and legume respectively. These yields were 12.2% and 19.9% higher over those obtained with 100% chemical fertilizer when used alone (Guerrero, 2008; Jeyabal,2001).

Vermicompost contains some antibiotics and actinomycetes that help in increasing the "power of biological resistance" among the crop plants against pest and diseases (Adhikary, 2012).

Several farms in world especially in North America, Australia and Europe are going organic as the demand for "organic foods" are growing in society. India has yet to appreciate the full importance of vermiculture despite the potential for the production of 400 million t of vermicompost annually from waste degradation (Sinha,1996). The Bhawalkar Earthworm Research Institute (BERI) is one of the largest non-governmental organisations involved in vermiculture practice at Pune in India and is operating a vermiculture plant on a commercial scale for the management of municipal wastes (Bhawalkar and Bhawalkar, 1994). In 1998, the Government of India announced exemption from tax liability to all those institutions, organizations, and individuals in India practicing vermiculture on commercial scale.